AIR FORCE OFFICE OF SCIENTIFIC RESEARCH [AFOSR]
The Basic Research Manager of the Air Force Research Laboratory

Research HIGHLIGHTS

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AUG
98

New Transistor Technology Doubles Performance Levels of Solid State Devices

ELIMINATES NEED FOR SUPPLEMENTAL ENVIRONMENTAL COOLING ON AIRCRAFT

Professor Mishra

A University of California (Santa Barbara) professor has produced an electronic device which doubles microwave power performance output compared to previously published results. The device is known as a modulation-doped field effect transistor (MODFET).

The demonstration of this device and collateral theoretical modeling indicate that solid state devices may potentially produce microwave power output levels rivaling those of vacuum tubes. This long-sought transition from vacuum tubes to solid state devices would mean:

- greater lifetimes for such Air Force applications as radar and electronic countermeasure systems;
- significant reductions in cost; and,
- improved reliability.

With AFOSR support, Prof. Umesh Mishra and his research team have explored electronic devices fabricated from a new class of semiconductor materials — gallium nitride (GaN) and related materials. While long recognized as promising for electronic and optoelectronic uses, GaN is a technically challenging material that only recently has had notable progress. Building on the progress from teams at Santa Barbara and elsewhere, Prof. Mishra has succeeded in producing new record levels of performance for the MODFET.

It also appears that the MODFET is capable of operation under uncooled conditions. This would mean that such devices would not require supplemental environmental cooling on an aircraft or on a space platform, resulting in a savings of weight, power consumption, and improved system reliability.

These research accomplishments are being transitioned to UCSB's industrial partners at Hughes Research Laboratory for potential insertion in a variety of Air Force and DoD electronic systems.

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USAF Airmen with ALQ-184 ECM pod at Hill Air Force Base, Utah

Photo: Raytheon Company

Novel Compliant Mechanisms Could Simpli

Professor Kikuchi

Professor Kota

"This research provides the opportunity to remove all moving parts from flight surfaces."

Researchers at the University of Michigan have developed a method to design single-piece, jointless mechanisms that may improve aircraft performance and simplify their design.

These devices, called compliant mechanisms, would allow the design of aircraft wings without control surfaces. This design modification provides the following benefits:

- reduces radar cross-section thereby improving stealth characteristics;
- reduces weight and complexity; and,
- increases aircraft maneuverability.

These monolithic structures are also very suitable for microelectromechanical systems (MEMS), which are critical to many next-generation U.S. Air Force weapon systems. Impressed by the potential of compliant mechanisms, the Air Force Research Laboratory's Air Vehicles Directorate has decided to continue development of the technology through the Small Business Innovation Research (SBIR) Program.

Professors Sridhar Kota's and Noboro Kikuchi's work is opening previously unachievable design possibilities. An aircraft wing based on a compliant mechanism would bend and twist as a single piece to control flight, eliminating separate control surfaces such as ailerons, spoilers, and flaps. This, in turn, simplifies construction and yields potentially much higher performance.

Compliant (flexible) structures thrive in nature. A blade of grass and certain cell membranes are good examples. Traditionally, however, engineered mechanisms tend to be strong and stiff, or non-compliant. This trend continues in current "smart" systems design. These systems rely on many smaller, rigid mechanisms and actuators that only simulate a compliant structure. However, if the underlying structure of smart systems were compliant, the resulting system would have vastly fewer jointed parts. This offers many benefits, including:

- simplified manufacturing (decreasing time and costs);
- easier and less system maintenance;
- more robust systems (fewer parts); and,
- lighter weight.

To be successful, compliant structures must offer the desired actuation characteristics and mechanical advantage but retain enough stiffness to resist external loads. These requirements led Dr. Kota, Dr. Kikuchi, and their students to develop a fundamentally new mathematical approach. It develops solutions based on prescribed boundary conditions and loading environments, and considers the kinematic, geometric, and continuum mechanics aspects of the problem. The researchers have created a finite-element, preprocessing program that quickly optimizes the cross-sectional shapes of various topologies.

Compliant mechanisms may lead to...

more maneuverable aircraft

better stealth characteristics

simplified construction

For a detailed technical explanation, please visit http://www-personal.engin.umich.edu/~kota.

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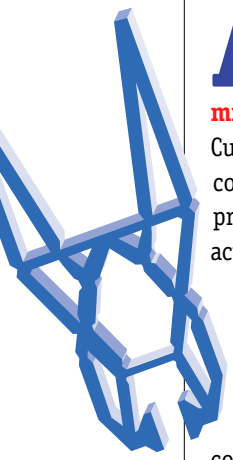
Aeroelastic Wing

RIGHT: The rendering at right represents a conceptual aircraft that uses compliant mechanisms to adapt the wing shape to improve aerodynamic performance. Current research programs to accomplish similar objectives are using external control surfaces such as leading and trailing edge flaps and other smart structures technology.

fy, Improve Aircraft

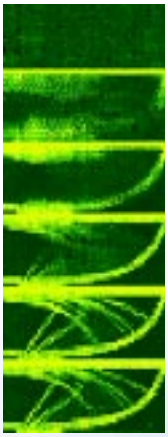
Jointless, Unibody Constructed Units



A Compliant Mechanism with jointless unibody construction

Actuators, the basic components which enable the mechanical operation of USAF systems, allow key weapon subsystems such as missile tail fins and aircraft flaps to operate. Current actuators have many parts with many connecting joints. Using traditional design and production methods produces strong and stiff actuator mechanisms.

However, a new methodology is emerging to design compliant mechanisms — jointless, unibody constructed units. These units are cheaper and easier to manufacture and offer more advantageous performance of how a finite element code starts from a blank design space and, in a series of steps, converges on a design solution for a compliant mechanism. The process, pictured to the right, adapts the mechanism shape based on a set of desired load and displacement conditions that describe specific structural operations. The final design in this simple example can be used to create the jointless, compliant tool shown above left.



The same process can design compliant actuators for a wealth of USAF smart structure applications, such as mission adaptive wings and vibration suppression systems. The code and step process was created by AFOSR-funded researchers at the University of Michigan.

Illustration: Catalyst Creative Partnership

Technology Transition Spotlight

In each issue, *Research Highlights* will feature a recent technology transition that benefits Air Force operations.

Customer ..... Electronics Systems Center (ESC) at Hanscom AFB has adopted the new "multi-frame most probable hypothesis" (MFMPH) tracking system approach to multi-sensor and multi-target tracking for an AWACS first-step upgrade for broad area surveillance. (The system, developed for ESC, won the "Best of Breed" national competition held by Mitre Corporation to determine the nation's best tracking system for AWACS.) The new tracking system will be deployed on five AWACS planes by mid-1999. Lockheed Martin of Owego, N.Y. is in charge of the transition and further development. The Boeing Company is the prime contractor.

Benefit ..... The new tracking system significantly improves AWACS surveillance capability by increasing the tracking capacity, fidelity, maneuver detection, tracking accuracy (kinematic information), and sensor fusion while decreasing computational throughput requirements compared to existing tracking systems.

Basic Research ... The new approach to multi-sensor and multi-target tracking is based on solving the central data association problem for multi-frame processing, which is formulated as an NP-hard combinatorial optimization problem called a multi-dimensional assignment problem, to the noise level in the problem. The new tracking system integrates estimation (filtering) and scoring (likelihood ratios) with data structures designed specifically for this MFMPH tracking system. This work is also the subject of two U.S. patents and one pending patent.

Performer ..... A research team led by Dr. Aubrey B. Poore of Colorado State University and Thomas N. Barker of IBM-Federal Systems (now Lockheed Martin) developed the initial approach. Dr. Poore's team continues the basic research program with transitions focusing on other Air Force Programs. AFOSR program manager:

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Photo: Stanford University

Dr. Steven Chu of Stanford University has received AFOSR and NSF funding since 1988 for basic research in developing methods to cool and trap atoms using laser light. (See MAR/APR 98 edition on-line for profile story)

1997 Physics Nobel Prize Co-Winner Comments on Basic Research Support

ON NEED FOR DEFENSE SUPPORT

"The money that funds basic research for defense has been dropping precipitiously… It's unfortunate because of the difference between DoD and NSF funding. Defense monitors are willing to go out on a limb, it isn't just a majority vote of peer-related science."

"This (basic research support) was one of the strengths of the U.S. scientific structure."

"The Department of Defense funded the development of the laser, the work done by Schalow and Townes, as well as at Bell Laboratories and AT&T. This type of funding is disappearing very rapidly because the military has a tremendous amount of pressure to have much more directed research than the far-reaching research of very long-term support."

ON VALUE OF BASIC RESEARCH INVESTMENT

"…Creates and maintains an 'in-house' (U.S.) talent pool."

History Lesson:
"China destroyed its entire education base during the Cultural Revolution… That experiment has been done."

"In times of stress, an overseas supplier may not supply."

Research Highlights

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Research Highlights is published every two months by the Air Force Office of Scientific Research. This newsletter provides brief descriptions of AFOSR basic research activities including topics such as research accomplishments, examples of technology transitions and technology transfer, notable peer recognition awards and honors, and other research program achievements. The purpose is to provide Air Force, DoD, government, industry and university communities with brief accounts to illustrate AFOSR support of the Air Force mission. *Research Highlights* is available on-line at:

http://www.afosr.af.mil

To access our web-site, click on the Research Products and Publications icon, then on *Research Highlights*.

NEXT ISSUE...

New Active Flow Control Technology

The demonstration of a new active flow control technology reduced jet engine exhaust temperatures on a full-scale JT8D-15 jet engine. Boeing C-17 aircraft engineers believe the technology may cut millions from jet engine life-cycle costs.

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